TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 431

EXPERIMENTS ON AIRFOILS WITH TRAILING EDGE CUT AWAY

By J. Ackeret

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Airfoils with their trailing edge cut away are often found on aircraft, as the fins on the hulls of flying boats and the central section of the wings for affording better visibility. It was therefore of some interest to discover the effect of such cutaways on the lift and drag and on the position of the center of pressure.

For this purpose, systematic experiments were performed on two different airfoils, a symmetrical airfoil No. 460 and an airfoil of medium thickness No. 508, with successive shortenings of their chords. The airfoils had a span of 1 meter (3.28 feet) and a chord of 20 cm (7.87 in.). Figs. 1 and 4 show the two airfoils in their original condition and the forms obtained by successive cutaways. By cutting away 2 cm (0.79 in.) at a time, the chord was finally shortened to 6 cm (2.36 in.). The cuts were perpendicular to the chord in No. 508 and perpendicular to the middle line in No. 460.

The coefficients obtained from the experiments refer to the areas or chords of the original airfoils and are designated by

*"Messungen an Profilen mit abgeschnittener Hinterkante," from "Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen," Report III (1927), pp. 82-86. See also J. Ackeret, "Versuche an Profilen mit abgeschnittener Hinterkante" in "Vorläufige Mitteilungen der Aerodynamischen Versuchsanstalt zu Göttingen," No. 2, 1924.

c_a', c_w' and c_m'. They are plotted in the usual manner in Figs. 2-6. The numerical values of the coefficients are given in Tables I-XVI. The results show an increase in the wing-section drag (or profile drag) with the increase in the height of the cut behind the airfoil, due to the negative pressure on this surface, as well as a reduction in the maximum lift. On the unsymmetrical airfoil No. 508, the center of pressure moves nearer the leading edge with increase in the portion cut away, as shown by the decrease in the c_m' values.

If the coefficients are based on the ground plans of the airfoils produced by the cutaways, a large increase in the maximum lift appears, along with considerable increase in the wing-section drag with the shortening of the chord. Figs. 7-8 show the values $c_{a_{max}}$ plotted against the chord, both with reference to the original chord $t = 20$ cm (corresponding to Figs. 2-3) and with reference to the new chords produced by the cutaways (i.e., $t = 20$ cm to $t = 6$ cm). In addition to the coefficients c_a', c_w' and c_m', Tables I-XVI also contain the coefficients based on the actual chords and areas resulting from the cutaways. These are designated by c_a, c_w and c_m.

The experiments show that small cutaways from the trailing edge make very little difference. Hence, no great importance should be attached to the extension of the trailing edge into a sharp point, this being merely a question of expediency.

I. Airfoil No. 508.

TABLE I.

a) Normal area.

b = 100 cm, t = 20 cm

α	100 c_a'=100 c_a	100 c_w'=100 c_w	100 c_m' = 100 c_m
− 9.0°	− 9.7	1.89	7.7
− 6.0	+ 9.4	1.61	12.3
− 3.1	29.6	1.96	17.1
− 0.2	48.6	2.89	21.6
+ 2.7	69.8	4.44	26.8
5.7	88.1	6.51	31.2
8.6	105.3	9.0	35.4
11.6	120.0	12.2	38.9
14.5	132.7	16.3	42.1
17.5	139.1	20.0	44.3
20.5	139.0	24.9	46.0

TABLE II.

b) t = 18 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
− 9.0°	− 10.2	2.06	5.2	− 11.3	2.30	6.5
− 6.0	+ 10.6	1.93	11.4	+ 11.8	2.14	14.0
− 3.1	30.4	2.42	15.9	33.8	2.70	19.7
− 0.2	49.7	3.32	20.5	55.3	3.70	25.4
+ 2.8	68.0	4.38	24.7	75.5	4.88	30.6
5.7	85.1	6.31	28.0	94.7	7.03	34.6
8.6	100.8	8.70	31.8	112.0	9.70	39.3
11.6	113.1	11.7	34.5	125.8	13.0	42.6
14.5	123.7	15.1	37.0	137.5	16.8	45.7
17.5	129.2	19.0	38.0	143.8	21.1	47.0
20.5	129.0	23.2	39.0	143.5	25.8	48.3

I. Airfoil No. 508 (Cont.)

TABLE III.

c) t = 16 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 8.9°	- 17.8	3.09	3.7	- 22.3	3.86	5.7
- 6.0	+ 1.1	3.10	7.6	+ 1.3	3.87	11.8
- 3.1	18.9	3.27	12.6	23.6	4.09	18.1
- 0.1	37.7	3.88	13.6	47.1	4.85	24.3
+ 2.8	55.7	4.35	19.8	69.5	5.43	30.9
3.8	64.1	4.57	21.2	80.1	5.71	33.1
5.7	72.2	5.56	23.1	90.4	6.96	36.1
8.7	86.5	7.56	26.1	108.0	9.45	40.7
11.6	101.5	10.1	29.3	127.0	12.7	45.6
14.6	112.5	12.9	31.3	140.5	16.1	48.7
17.6	119.6	16.2	32.4	149.3	20.3	50.5
20.6	121.8	19.7	32.7	152.1	24.7	51.0
21.6	121.8	21.1	32.9	152.1	26.3	51.2

TABLE IV.

d) t = 14 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 6.0°	- 3.6	4.34	5.3	- 5.1	6.19	10.8
- 3.0	+ 12.5	4.44	8.5	+ 17.8	6.33	17.3
- 0.1	28.9	4.78	11.8	41.1	6.82	24.1
+ 2.8	45.2	5.14	15.3	64.5	7.34	31.1
5.8	62.1	6.20	18.7	88.6	8.78	38.2
8.7	77.9	7.65	21.5	109.8	10.9	43.8
11.7	90.0	9.55	23.9	128.4	13.6	48.7
14.6	100.0	11.8	25.7	142.8	16.8	52.4
17.6	107.3	14.5	26.8	153.0	20.7	54.5
20.6	110.3	17.6	27.3	157.4	25.0	55.7
21.6	110.0	18.6	27.4	156.9	26.5	55.9

I. Airfoil No. 508 (Cont.)

TABLE V.

e) t = 12 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 8.9°	- 32.7	7.14	- 2.0	- 54.5	11.9	- 5.4
- 5.9	- 18.2	6.38	0.0	- 30.4	10.6	0.0
- 3.0	- 0.3	6.20	+ 3.8	- 0.6	10.3	+10.4
- 0.1	+ 16.1	6.20	7.3	+ 26.8	10.3	20.3
+ 2.9	31.0	6.49	10.3	51.6	10.8	28.5
5.8	45.5	6.95	12.5	75.8	11.6	34.6
8.8	60.7	8.12	15.9	101.1	13.5	44.2
11.7	74.9	9.30	18.2	124.8	15.5	50.5
14.7	85.8	10.8	20.0	143.0	18.0	55.6
17.7	94.1	12.5	21.5	156.9	20.8	59.6
20.6	100.3	14.7	22.2	167.0	24.5	61.7
21.6	100.7	15.6	22.2	168.0	26.0	61.7

TABLE VI.

f) t = 10 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 3.0°	-11.4	7.52	- 0.2	- 23.3	15.3	- 0.8
0.0	+ 1.1	7.72	+ 2.1	+ 2.2	15.7	+ 8.8
+ 2.9	15.1	8.10	4.7	30.7	16.5	19.5
5.9	29.2	8.23	7.1	59.5	16.8	29.8
8.8	41.8	8.63	9.4	85.1	17.6	39.4
11.8	53.8	9.45	11.5	109.7	19.2	48.2
14.8	65.9	10.5	13.7	134.3	21.5	57.1
17.7	76.8	11.4	15.5	156.5	23.3	64.8
20.7	83.5	12.2	16.4	170.0	24.8	68.5
22.7	87.5	13.2	17.1	178.6	26.9	71.4
23.7	90.1	14.5	16.9	183.8	29.5	70.5
24.7	88.6	15.5	16.3	180.7	31.6	68.0
25.7	75.2	19.9	14.2	153.2	40.7	59.2

I. Airfoil No. 508 (Cont.)

TABLE VII

g) t = 8 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 2.9°	-15.8	9.40	- 1.1	- 39.4	23.5	- 7.0
0.0	- 5.1	8.42	+ 0.3	- 12.7	21.0	+ 2.0
+ 3.0	+ 5.1	8.95	1.9	+ 12.8	22.4	11.9
5.9	16.0	9.61	3.1	39.9	24.1	19.6
8.9	28.2	10.0	5.7	70.4	25.1	35.5
11.9	37.9	10.1	6.7	94.5	25.3	41.7
14.8	48.0	11.0	8.4	119.7	27.5	52.4
17.8	57.8	11.7	10.0	144.3	29.2	61.7
20.8	67.1	12.5	11.6	167.3	31.1	72.7
23.7	74.2	12.6	11.5	185.4	31.6	71.7
25.2	74.7	13.4	10.7	186.5	33.5	67.9
26.8	64.4	17.6	10.1	160.7	44.0	63.0

TABLE VIII.

h) t = 6 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
0.0°	-11.2	9.9	- 1.0	- 37.3	33.0	-11.4
3.0	- 2.6	9.6	- 0.3	- 8.7	32.0	- 3.2
6.0	+ 5.1	9.9	+ 0.4	+ 17.1	33.1	+ 4.7
9.0	13.6	10.9	1.2	45.2	36.3	12.9
11.9	23.3	11.2	2.3	77.6	37.3	26.1
14.9	32.1	10.9	3.5	107.0	36.5	38.6
17.9	40.1	10.9	4.8	133.8	36.2	53.0
20.8	47.0	11.4	5.2	156.8	38.1	56.6
21.8	50.9	11.4	5.3	169.7	38.1	59.2
22.8	52.8	11.3	5.5	176.0	37.9	61.4
25.8	55.1	12.0	5.8	183.8	40.0	64.0
26.3	56.3	12.5	4.9	187.8	41.8	54.1
27.8	49.0	14.9	5.1	163.5	49.5	57.0

II. Airfoil No. 460.

TABLE IX.

a) Normal area.

$b = 100$ cm, $t = 20$ cm

α	$100\ c_a'=100\ c_a$	$100\ c_w'=100\ c_w$	$100\ c_m'=100\ c_m$
-2.9°	-19.5	1.56	- 3.8
0.0	- 1.6	1.20	- 0.2
+ 2.9	+17.4	1.34	+ 4.0
5.9	36.8	2.07	7.9
8.8	54.7	3.37	12.0
11.7	71.5	5.12	16.5
14.7	88.0	7.60	19.5
17.6	97.0	10.8	21.9
18.6	98.4	12.1	23.2
19.7	78.9	19.1	22.3
20.7	79.1	21.1	23.0

TABLE X.

b) $t = 18$ cm

α	$100\ c_a'$	$100\ c_w'$	$100\ c_m'$	$100\ c_a$	$100\ c_w$	$100\ c_m$
-2.9°	-21.0	2.22	- 4.5	-23.4	2.45	- 5.6
0.0	- 1.2	1.89	+ 0.0	- 1.3	2.10	+ 0.1
+ 2.9	+18.0	2.05	4.4	+20.0	2.27	5.4
5.9	37.0	2.58	8.7	41.1	2.87	10.7
8.8	54.9	3.74	12.4	61.1	4.15	15.3
11.7	75.2	6.06	18.0	83.6	6.73	22.2
14.7	87.4	7.81	19.6	97.0	8.69	24.1
17.7	95.2	10.2	20.7	105.8	11.4	25.6
18.7	95.4	11.5	20.7	105.9	12.7	25.5
20.7	76.0	19.8	19.7	84.5	22.1	24.3

II. Airfoil No. 460 (Cont.)

TABLE XI.

c) t = 16 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 2.9°	-17.4	3.53	- 3.6	- 20.7	4.41	- 5.6
0.0	+ 0.8	3.39	+ 0.3	+ 1.0	4.24	+ 0.5
+ 2.9	19.6	3.53	4.8	24.5	4.41	7.4
5.9	39.5	4.20	9.4	49.4	5.25	14.7
8.8	58.2	5.09	13.5	72.8	6.36	21.1
11.7	73.7	6.56	16.6	92.0	8.20	25.9
14.7	86.5	8.66	18.7	108.0	10.8	29.1
17.7	93.3	11.1	19.7	116.4	13.9	30.7
18.7	94.0	12.2	19.5	117.3	15.3	30.4
20.7	74.0	20.2	17.9	92.4	25.2	27.9

TABLE XII.

d) t = 14 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 2.9°	-21.2	4.49	- 4.5	- 30.3	6.40	- 9.1
0.0	- 2.5	4.49	- 0.2	- 3.7	6.40	0.0
+ 2.9	+15.5	4.49	+ 3.7	+ 22.1	6.11	+ 7.5
5.9	32.6	4.44	7.1	46.7	6.35	14.4
8.8	49.6	4.83	10.8	71.0	6.90	22.1
11.8	66.0	6.39	14.2	94.4	9.15	28.9
14.7	81.5	8.75	17.2	116.3	12.5	35.1
17.7	90.4	10.3	18.3	129.0	14.7	37.4
18.7	91.7	11.1	18.3	131.0	15.9	37.3
19.7	91.9	12.1	18.2	131.5	17.2	37.1
20.7	86.9	13.8	15.4	124.0	19.7	31.6

II. Airfoil No. 460 (Cont.)

TABLE XIII.

e) t = 12 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 5.9°	-32.8	7.55	- 6.3	- 54.8	12.6	-17.5
- 2.9	-17.5	6.84	- 3.3	- 29.2	11.4	- 9.1
0.0	- 1.0	6.84	- 0.1	+ 1.7	11.4	- 0.4
+ 2.9	+14.9	6.80	+ 3.5	24.9	11.3	+ 9.8
5.9	30.3	7.21	6.1	50.5	12.0	16.9
8.8	45.0	8.19	10.2	74.1	13.6	24.8
11.8	59.6	9.34	11.7	99.5	15.6	32.6
14.7	73.6	10.7	14.5	122.7	17.8	40.2
17.7	85.4	11.8	16.4	142.1	19.7	45.5
19.2	88.0	12.6	16.7	146.8	20.9	46.5
20.7	83.5	14.3	15.3	139.0	23.8	42.5

TABLE XIV.

f) t = 10 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
- 2.9°	-16.9	9.25	- 2.8	- 34.4	18.9	-11.7
0.0	- 2.8	8.60	- 0.3	- 5.7	17.4	- 1.4
+ 3.0	+ 9.1	8.90	+ 1.7	+ 18.5	18.2	+ 7.1
+ 5.9	22.9	9.36	4.3	46.8	19.1	17.9
8.9	35.3	9.63	6.3	71.9	19.6	26.2
11.8	47.5	10.4	8.1	96.8	21.2	33.6
14.8	59.2	11.5	10.4	120.6	23.3	43.1
17.7	70.9	12.4	11.9	144.4	25.2	49.5
19.7	77.0	12.6	12.7	157.0	25.6	52.6
20.7	79.1	13.4	12.7	161.1	27.2	53.1
21.7	78.6	14.1	12.0	160.2	27.9	50.1
22.6	72.4	16.0	11.1	147.4	32.7	46.4
22.8	63.6	18.0	10.5	129.5	36.7	43.8

II. Airfoil No. 460 (Cont.)

TABLE XV

g) t = 8 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
-3.0°	- 9.8	10.8	- 1.6	- 24.5	27.1	- 9.8
0.0	+ 0.1	10.6	+ 0.1	+ 0.3	26.4	+ 0.4
+ 3.0	10.8	11.1	1.6	27.1	27.7	10.1
5.9	22.1	11.8	3.6	55.2	29.3	22.3
8.9	32.8	11.8	5.1	82.0	29.6	31.8
11.8	42.7	12.2	6.6	106.5	30.6	41.3
14.8	52.9	13.1	8.0	132.0	32.8	50.1
16.8	59.1	13.7	9.0	147.2	34.1	55.9
19.7	68.2	14.1	10.3	170.1	35.3	64.1
22.7	69.2	14.6	9.3	172.7	36.5	57.9
23.8	44.0	21.1	6.7	109.8	52.6	41.8

TABLE XVI.

h) t = 6 cm

α	100 c_a'	100 c_w'	100 c_m'	100 c_a	100 c_w	100 c_m
-3.0°	- 8.4	12.5	-1.0	- 28.0	41.6	-11.3
0.0	- 0.7	12.3	0.0	- 2.3	41.2	+ 0.3
+ 3.0	+ 6.9	12.4	+1.0	+ 22.9	41.5	11.3
6.0	13.9	12.9	1.9	46.5	42.9	21.2
8.9	21.7	13.9	3.3	72.4	46.2	36.8
11.9	30.5	13.7	3.8	101.5	45.7	42.6
14.9	38.2	13.5	4.9	127.2	44.8	54.8
17.8	44.8	13.8	5.7	149.1	46.1	63.5
20.8	50.5	13.6	6.4	168.2	45.5	70.7
22.8	52.2	13.5	6.0	173.7	45.0	66.6
23.8	45.0	17.0	5.2	149.9	56.5	58.3

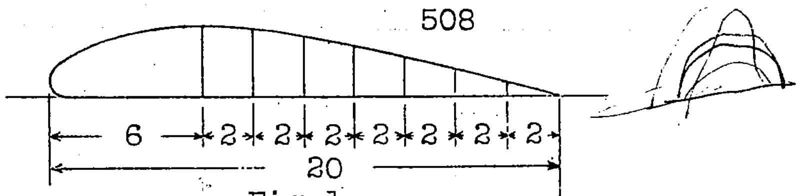

Fig.1

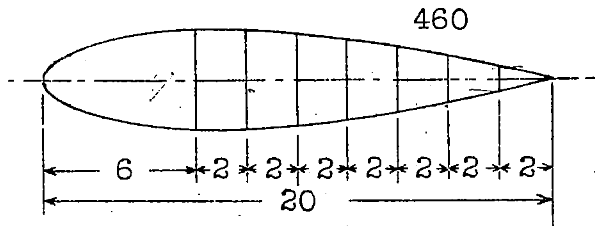

Fig.4.

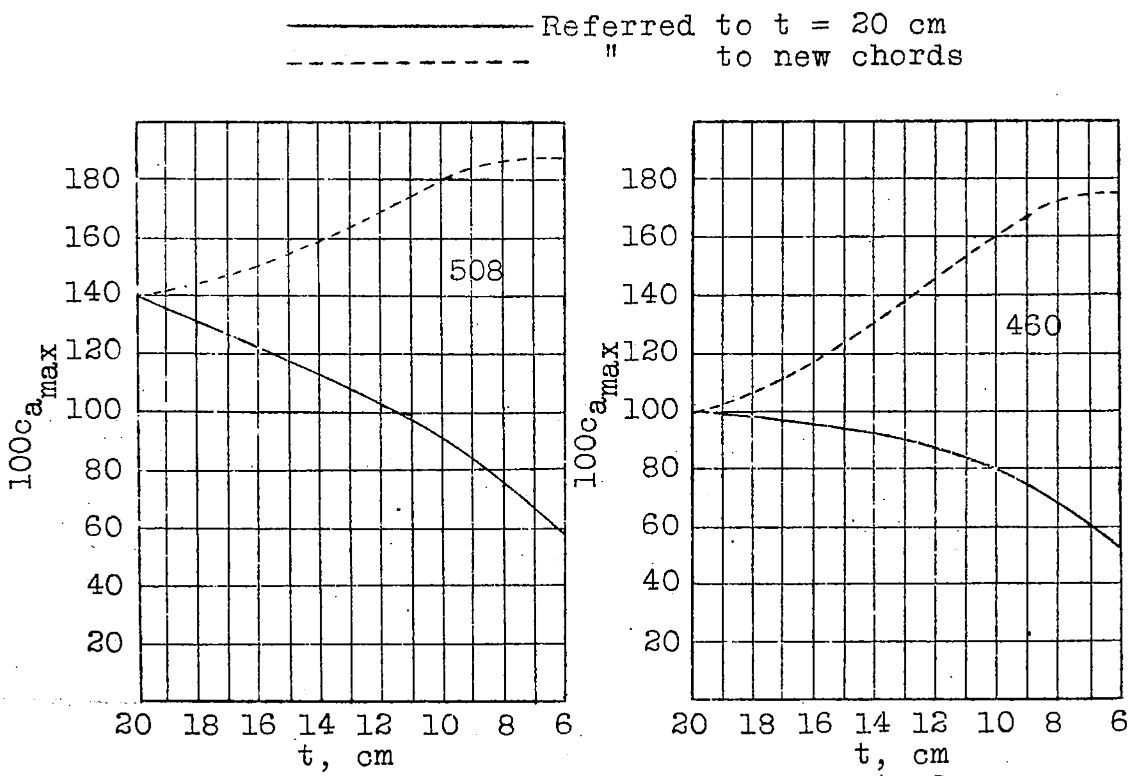

Fig.7.

Fig.8.

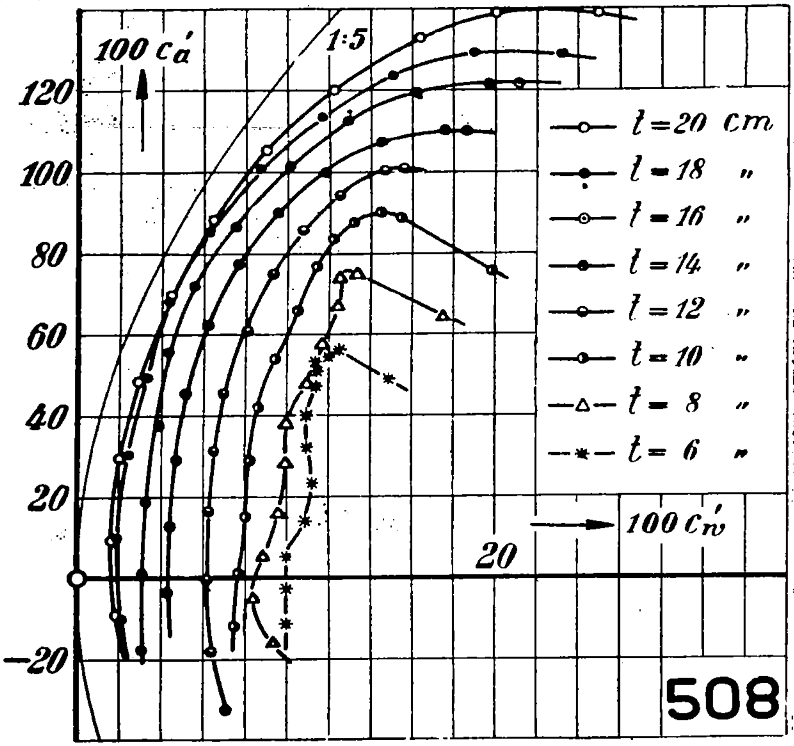

Fig. 2

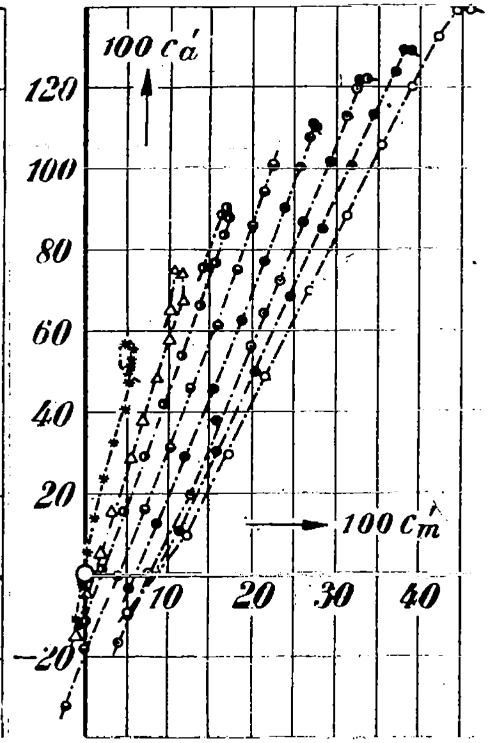

Fig. 3

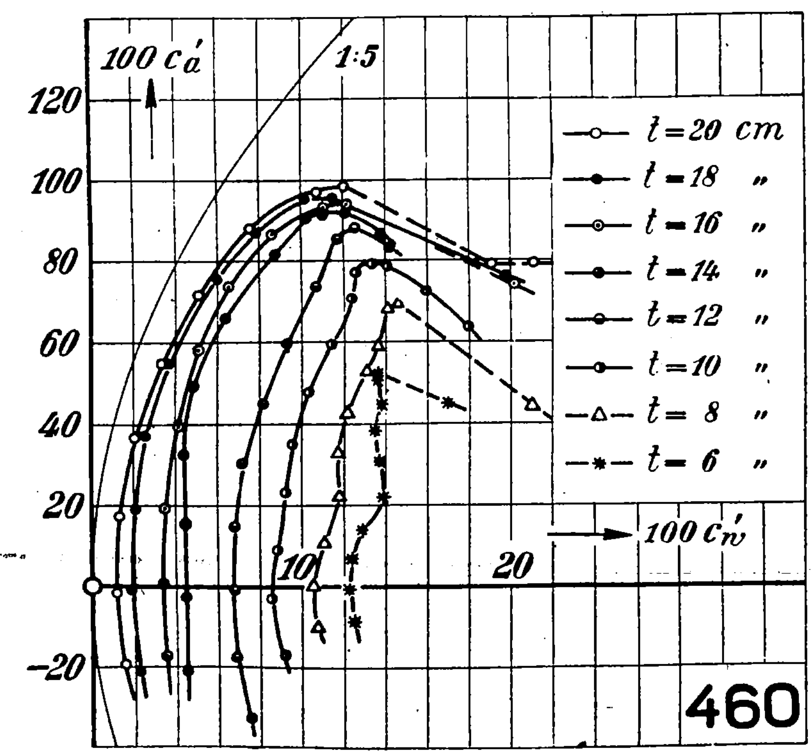

Fig. 5

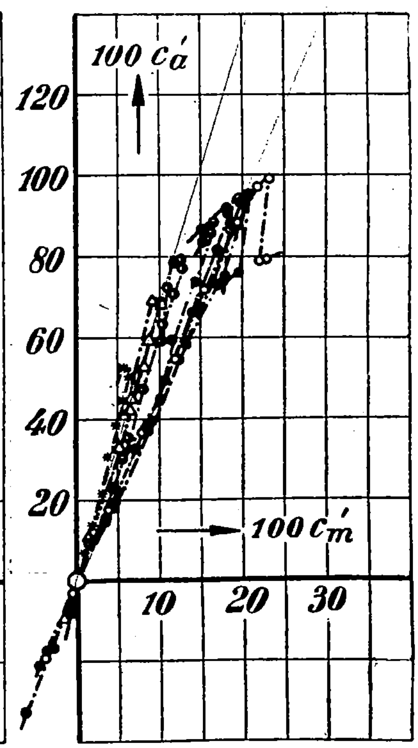

Fig. 6